Review of

California Environmental Protection Agency
California Air Resources Board

PROPOSED AMENDMENTS TO THE CALIFORNIA DIESEL FUEL REGULATIONS

STAFF REPORT: INITIAL STATEMENT OF REASONS
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OVERVIEW

This is one of four independent peer reviews provided on the staff of the Air Resources Board proposed changes and additions to regulations for California reformulated diesel including a new standard for lubricity. These reviews are prepared under Interagency Agreement #98-004 between the University of California and the California Environmental Protection Agency, the California Air Resources Board (ARB). This review also treats the ARB staff assessment of the emissions reductions associated with the current California Reformulated Diesel regulations, which were adopted in 1988 and became effective in 1993. Some, but not all, of the provided additional references and references cited in the report also have been reviewed.

MAJOR REVIEW CONCLUSIONS

The staff report provides a justification for the need for new diesel fuel regulations and a convincing assessment of the effect of the new regulations on the reduction of emissions that is consistent with the currently available technical data. The three most important issues that would benefit from additional attention are:

1) ***The role oxygenate additives in diesel fuel formulation; the impact of the regulations on oxygenate additives; the distinction among diesel, alternative diesel fuels, and their blends; and the impact of all of these on emissions needs further clarification and exposition.***

2) ***The adequacy of the equivalency specification to provide comparable or better emissions reductions across the range of diesel engine applications is questioned because its derivation is not clearly explained and that data set upon which it is based is judged inadequate.***

3) ***The accuracy of relating the lung cancer health benefits from reformulation to particulate mass reduction when reformulation is likely to have greater or lesser effect on reducing the specific carcinogenic compounds is questioned.***

4) The lubricity standard may not be needed. It might be better policy to leave responsibility for adequate lubricity with the refiners, where it is now.

Discussion of these issues appears in more detail in the following text.

Additional recommendations dealing with other issues also follow in the more detailed review of each section of the report.

REVIEW

The details of my review follow the structure of the staff document: *Proposed Amendments to the California Diesel Fuel Regulations, Staff Report: Initial Statement of Reasons,* dated June 6, 2003

I. INTRODUCTION AND SUMMARY

This section provides an appropriate and concise overview of the need for and nature of the proposed regulation.

The current diesel fuel regulation applies to on-road fuel consumption, limits sulfur to 500 ppmw, and limits aromatics to 10% with an exception to 20% for small refiners and an equivalency alternative based on demonstration for large refiners. Most refiners use the equivalency alternative and produce diesel fuels with more than 10% aromatics.

The proposed diesel fuel regulation applies to both on-road and off-road fuel consumption (but excludes diesel fuels used exclusively in locomotive or marine engines), drops

the sulfur limit to 15 ppmw and retains the nominal limit on aromatics of 10% but specifies equivalency limits that allow refiners alternatives to meeting the aromatic limit. Additionally, the new regulations propose a new lubricity standard, new requirements for certifying alternative formulations, a new (emissions) certification fuel, a new sulfur test method, and an exemption for qualifying military vehicles.

The primary reason to reduce sulfur is to enable the exhaust emissions control technology (catalyzed traps for particulate control and NOx adsorbers for NOx control) that are likely to be applied for diesels to meet the 2007-2010 heavy duty emissions standards and 2007 light duty emission standards. Since the U.S. Environmental Protection Agency will impose a 15 ppmw sulfur limit on diesel fuel during 2006, the other fuel specifications, applications, and procedures are additional to the EPA requirements and are the items of primary importance. The ARB staff correctly believes that requirements additional to those of the EPA are essential to providing the additional emissions reductions needed to meet California air quality goals. Extending the fuel requirement to off-road applications will provide emissions reductions from existing engines and enable the application of on-road emissions control to the off-road engines. The other changes are largely procedural and primarily designed to ease implementation, improve the effectiveness of implementation, and to provide additional flexibility. They primarily retain the emissions reductions of the current fuel rather than provide additional emissions reductions.

II. RECOMMENDATIONS

This section succinctly lists the eight primary recommended board actions. The first two, reducing sulfur to 15 ppmw and extending application of reformulated diesel to most diesel applications, but not locomotive and marine engines, are the primary actions. The remaining six are primarily procedural—but some difficulties may be associated with these details.

III. BACKGROUND

The factual description of diesel fuels and engines and their use and application in California is complete. The emission inventory estimates are reasonable but contain the uncertainties inherent to the EMFAC model from which they are produced. The dependency of emissions upon fuel properties is complex with many of the properties interdependent, which makes associating emissions dependence upon single fuel parameters difficult. This will be discussed more in Section IX.

IV. NEED FOR EMISSIONS REDUCTION

The need for further diesel emissions reductions is tied by the staff report to both criteria (ozone, carbon monoxide, and particulate matter) and toxics. Diesels are small contributors to the VOCs and CO inventory. Fuel reformulation has a small effect on the emissions of VOCs and CO and an even smaller effect on the inventory. Therefore the focus should be on NO_x, PM, and toxics.

Since the NO_2 air quality standard is met statewide, it is the role NO_x in the production of ozone and nitrate particulates that is of interest. The discussion of diesel NO_x and ozone ignores the increased understanding that much of the state is and is becoming hydrocarbon limited. In some areas additional NO_x reduction will make attainment of ozone standards more difficult, that is, will require even greater VOC reduction. Additionally, Figure IV-1 would benefit from some clarification. I believe that this figure is for the 1-hour ozone standard and should be so stated. Mention of the 8-hr ozone standard and its implication to California should be made. Also, the designations are by air basins whereas presenting the maps by counties, while correct in a regulatory context, gives the wrong implication for the air quality of various regions of the state.

The pending $PM_{2.5}$ designations and the increased relative contribution and importance of diesel particulate emissions should be mentioned.

The uncertainty in predicting risk of death from lung cancer from diesel particulate exposure is high. While reporting such risks, Table IV-1, may be useful in supporting regulations, it is improper to do so without quantifying or at least mentioning the uncertainty.

V. HEALTH BENEFITS OF DIESEL EMISSIONS REDUCTIONS

The discussion of diesel particulate health effects (page 28) lacks any explicit mention of ultrafines and the increasing understanding of the mechanism of their adverse health effects, and increasing concerns. The known relation between fuel properties and particulate emissions is primarily for particulate as PM_{10} or TPM, Data are largely lacking, but needed, that relate fuel properties to $PM_{0.1}$. Reducing sulfur content will reduce ultrafine, some of which result from the condensation of sulfuric acid.

VI. EXISTING DIESEL FUEL REGULATIONS

The summary and discussion of diesel fuel regulations is clear and useful.

VII. PM RISK REDUCTION ACTIVITIES

This section provides a factual accounting of diesel PM reduction activities in the state.

VIII. PROPOSED AMENDMENTS TO SULFUR STANDARD FOR CALIFORNIA DIESEL

The statement (page 42) that current sulfur levels prevent effective operating of NO_x control technology is not strictly true if the possibility of selective catalytic reduction (SCR) is included. I agree that NO_x adsorption control technology is preferable and likely. However, this technology is not fully demonstrated and the competing SCR technology is seeing widespread application in Europe. There should be some mention of SCR and assessment of its sulfur tolerance.

IX. PROPOSED AMENDMENTS TO THE DIESEL ENGINE CERTIFICATION FUEL REGULATION

Changing the fuel used to certify new engines beginning in 2007 to reflect the 2006 reformulated diesel fuel (RFD-2006) is appropriate. The properties specified in Table IX-1 (page 49) are reasonable and appropriate.

X. PROPOSED AMENDMENTS TO REGULATORY PROVISIONS ON CERTIFIED ALTERNATIVE DIESEL FUEL FORMULATION

The concept of an alternative diesel fuel formulation that has properties constrained by those of a "candidate fuel" shown to yield emissions less than or equal to those of the "reference fuel") is established to provide refiner flexibility while retaining emissions reductions. One issue that is not made clear in the staff report is just how emissions equivalency is to be demonstrated beginning in 2007 when on-road engines with new aftertreatment systems start to appear and the use of RFD-2006 in off-road engines begins. Ideally emissions equivalency would be obtained and demonstrated across the range of applications. Practically, emissions equivalency demonstration is important for three categories of engines, 1) pre-2007 on-road heavy-duty engines, 2) 2007 and later on-road heavy-duty engines, and 3) off-road engines. Essentially all of the data relating emissions to fuel properties are for pre-2002 on-road heavy-duty engines. Presumably the details of working out just how emissions equivalency is to be demonstrated is left to the staff and approval of the ARB Executive Officer. This issue needs to be addressed.

Tightening test tolerances and the elimination of the sulfate credit are appropriate actions.

XI. PROPOSED NEW FUEL SPECIFICATIONS FOR EQUIVALENCY TO THE AROMATIC HYDROCARBON LIMIT

In addition to providing for the sale of alternative fuel formulations by demonstration through test of equivalent emissions reductions, a general equivalency to the aromatic hydrocarbon limit is proposed that places limits on five fuel properties (aromatic content, PAH content, API gravity, Cetane Number, and Nitrogen Content) as specified in Table XI-3. The absolute 15 ppmw sulfur limit, of course, also applies to the alternative fuel. This equivalent limit specification is a key element of the proposed RFD-2006 regulation. Confidence that any fuel within these equivalent limits provides equivalent emissions reductions to the reference fuel derives from data summarized in the report *Staff Review of the Emissions Benefits of California's Diesel Fuel Program,* March 2003 (Draft) presented in Appendix D. While the data base is greatly expanded beyond that available at the time the original California RFD regulations were adopted (and reassuringly confirms the originally estimated emissions reductions) it is dominated by 1998 and earlier on-road diesels with a few tests of 2004 prototype on-road diesels. There is little off-road engine emissions data and, of course, no data from 2007 on-road diesel technology.

How the equivalent limits for the five properties were derived from the emissions data base is not clear. The first four properties are interdependent and most of the tests were not designed to extract the effect the change of a single property. The effect of Cetane Number can be examined over a limited range through the use of Cetane Number improver additive. The effect of fifth property, nitrogen content, which in practice is primarily associated with the Cetane Number improver additive, can also be varied independently of other fuel properties. It is impossible to assure that all fuels within the specified equivalent limits would match of exceed the emissions reductions of the reference fuel. Additionally, there is no basis for confidence that the emissions reductions also apply to off-road diesel engines or to 2007 and later on-road diesel technology. Note that the 2007 and later issue is not of practical significance since the emissions should be so low that fuel effects for this segment will have a minor affect on the inventory.

There is some evidence for concern that the data used by the ARB to establish fuel property—emissions relations are not applicable to off-road engine and duty cycles. The EPA report *Strategies and Issues in Correlating Diesel Fuel Properties with Emissions—Staff Discussion Document,* EPA420-P-01-00, July 2001, which is based largely on non-road diesel

engines, shows a lower impact of CFD on particulate mater reduction that reported by the ARB which is based largely on on-road diesel engine tests.

XII. PROPOSED REGULATION ESTABLISHING A DIESEL FUEL LUBRICITY STANDARD

The basic issue of a lubricity standard is whether or not it is needed. The alternative is to trust that the refiners as part of their product quality control and customer satisfaction concerns would assure an adequate level of lubricity in their product. Since the heavy hydrodesulphurization necessary for sulfur reduction is likely to reduce lubricity there is a potential for a problem if corrective action were not taken by refiners. A secondary issue is whether the proposed test, the High Frequency Reciprocating Rig test (ASTM standard D6079-02) and wear scar diameter limit of 520 microns is appropriately protective, or even the right test. Since level of protection provided by the proposed lubricity standard approximates the industry's current voluntary standard, the practical impact may be negligible. By adopting such a standard will the ARB be assuming responsibility for a quality control issue that is properly the responsibility of the refining industry?

XIII. OTHER PROPOSED AMMENDMENTS TO THE DIESEL FUEL REGULATIONS

The need to switch to a more sensitive test for fuel sulfur is certain. The proposed ultraviolet fluorescence method, ASTM D5453-93 is appropriate.

The proposed definition of diesel fuel is not clearly stated. This is a much bigger issue than might at first be perceived or than is indicated by the very limited discussion. One might argue that any fuel used in a compression ignition engine is a diesel fuel. The ARB does not intend that this regulations should apply to alternative diesel fuels (note that the word "alternative" is used in two different contexts: first as in an alternative formulation of conventional diesel and second as in an alternative to conventional diesel. Unfortunately the

distinction between diesel fuels and alternative diesel fuels is vague, especially when it comes to blends of alternative and petroleum based diesel fuels. The description “any liquid fuel that is predominantly a mixture of hydrocarbons” leaves uncertainties about the inclusion of biodiesel, esters of biodiesel, and their blends with petroleum diesel and/or liquid diesel fuels derived from natural gas, coal, or biofeedstocks. The addition of a variety of oxygenates to diesel is an effective way to reduce particulate emissions and this possibility should not be eliminated or discouraged by the definition of diesel fuel or the specifications.

XIV. FEASIBILITY OF REFINING LOW SULFUR DIESEL FUEL

The discussion of refining options confirms that adequate technology exists to provide low sulfur reformulated diesel fuel. This technology either already exists at California refineries or can be acquired.

XV. POTENTIAL IMPACTS OF THE PROPOSED SPECIFICATION ON THE PRODUCTION OF DIESEL FUEL BY CALIFORNIA REFINERIES

The ARB review identifies no barriers to providing the required diesel fuel. Since similar low sulfur on-road diesel fuels will be required nationally at the same time, differences between California and Federal reformulated diesel fuels will be small. The ARB may want to consider allowing the temporary use of diesel fuel meeting Federal specifications should an unforeseen shortage arise.

XVI. OTHER ISSUES

Exemptions for small refiners have always been a problematic but expedient policy. While exemption from the aromatic content limits is not a big deal, exemption from the sulfur limit is because of its affect on aftertreatment technology, including both increased emissions

and possible damage to emissions control equipment. The ARB may want to consider as a possible relief measure, if necessary, the diversion of diesel fuel with greater than 15 ppmw sulfur to off-road applications where new exhaust aftertreatment technology has not been applied.

The role of lubricant and concern for sulfur and additives on emissions is outlined in the report. This issue is being studied and understanding improved. The ARB should commit to participating in these studies and working for the national adoption of lubricant standards, if necessary, to treat emission system and emission effects.

A description of biodiesel fuels is provided. It might be noted that Fischer-Tropsch diesel can be derived from coal, biowastes, cellulose, and other feedstocks—not only natural gas. Again, it is not clearly stated that alternative diesel fuels are to be excluded from this regulation and, if so, what level of blending divides alternative diesel fuels from the regulated diesel fuels. This issue needs to be clarified least the use of biodiesel, biodiesel-diesel blends, oxygenate additives, and other "unconventional" diesel fuels that have emissions reduction and renewable advantages be excluded by this regulation.

It is reassuring that similar low sulfur diesel reformulation is occurring internationally. The report does not discuss the future possibility of a zero sulfur diesel fuel as called for in the World-Wide Fuel Charter. If and how the ARB will address this issue in the future should be included.

XVII. ENVIRONMENTAL EFFECTS OF THE PROPOSED AMENDMENTS TO THE DIESEL FUEL REGULATIONS

The ARB provides a multimedia analysis of the effects of the proposed diesel fuel regulations in satisfaction of the California Environmental Quality Act (CEQA) and ARB policy.

They judge all air quality effects to be positive. One pollutant for which this may not be true is NO_2. Both the catalyzed trap technology and NO_x adsorption technology have the potential to convert NO to NO_2. While NO_x is reduced in the process it is possible that NO_2 emissions could increase. Sulfur inhibits this conversion, probably in both technologies, hence the lower the sulfur the higher the NO_2. While the effect may negligible, the possibility needs to be discussed. Also the possible adverse affect of NO_x reduction on ozone in some areas of California, raised earlier, needs to be considered.

The new technology also is likely to increase the conversion of sulfur to SO_3 and sulfate. With the large proposed reduction of fuel sulfur the net result should be a lowering of SO_3 and sulfate. This needs to be discussed and confirmed.

The issue of greenhouse gas emissions is a bit more complex than indicated in the ARB analysis. It is possible that N_2O emissions will be increased by one or both of the exhaust treatment devices and that the conversion of NO to N_2O may be affected by fuel composition. Little or no data exist on this subject but the possibility should be noted. Also, black carbon is thought to contribute to global climate change. Since RFD-2006 reduces particulate matter and diesel particulate matter is largely black carbon, the effect will reduce climate change effects. This should be noted in this section (it is acknowledged later).

Effects on water quality are judged to be insignificant. One possibility is any use of an additive to assist in meeting emissions equivalency that in turn might have an adverse effect on water quality. There is no indication that this is planned.

XVIII. COSTS TO PRODUCE LOW SULFUR DIESEL FUEL

Cost analyses of fuel modifications are always difficult to make because they can vary widely from refinery to refinery and the needed information is proprietary. The ARB staff has not attempted a refinery by refinery cost estimate. This is reasonable. The cost estimates are consistent with other analyses of desulfurization. One statement that needs qualification or removed appears on page 122 is “Staff’s evaluation of this proposal [to reduce sulfur levels

below the current proposed regulation] concluded that the reductions in fuel sulfur below 15 ppmw would result in significant cost increase with little or no increase in benefits." This statement would seem to close the door on future consideration of the proposals of the World Wide Fuel Charter's call for a sulfur-free fuel. If the statement is to remain then it must be justified with a documentation of the referenced analysis. There are issues of engine and aftertreatment durability that are affected by fuel sulfur level. The understanding of these effects is currently is judged insufficient for a reliable cost benefit analysis. A more conservative approach, considering the uncertainties, would be to eliminate the statement.

XIX. ECONOMIC IMPACTS OF THE PROPOSED AMENDMENTS TO THE DIESEL FUEL REGULATIONS

The economic impact analysis is based on based on a modification of the Dynamic Revenue Analysis Model. It predicts no significant impact on the California economy. Negative impacts accrue primarily to the refining, agricultural, and trucking sectors. Differential effects with adjoining states should be reduced from current levels because of the coincident adoption of the Federal low sulfur diesel fuel requirements.

XX. NEED FOR NONVEHICULAR DIESEL-ENGINE FUEL REGULATION

The ARB staff ties the need for non-vehicular diesel-engine fuel regulations to a proposed Airborne Toxicant Control Measure (ACTM). This sector consists of stationary, portable, and transportation refrigeration unit (TRU) diesel engines. Considering the uncertainty and controversy related to diesel emission toxicity, justification through their contribution to the criteria pollutants, NO_x and PM would seem useful in addition. The PM emission inventory of Table XX-1 lumps the three elements above with locomotive and marine contributions. It would seem reasonable to break non-vehicular sources into the five separate categories: stationary, portable, TFU, locomotive, and marine diesel.

This in turn raises the question of why locomotives and marine diesels are not included in the RDF-2006 regulation. If there are policy or legal reasons for their exemption, they should be explained as part of the report. If such reasons do not exist, then not including locomotives and marine diesels is a major shortcoming.

APPENDICES

The appendices are both informative and, in some cases, supportive of the proposed regulations.

APPENDIX A: Provides the wording of the changes to the FRD-2006 regulation.

APPENDIX B: Provides the wording changes to exhaust emissions standards and test procedures.

APPENDIX C: Provides background information on diesel fuel aromatic content and polycyclic aromatic hydrocarbon (PAH) emissions. Since many of PAHs (and their nitrate derivatives) are known human carcinogens, much of the attention on diesel PM carcinogenicity has focused on these compounds.

APPENDIX D: This appendix presents a key document, *Staff Review of the Emissions Benefits of California's Diesel Fuel Program,* which was discussed earlier. The primary conclusion of this reviewer is that the data base is insufficient to characterize the effect of fuel changes on emissions from new technology (not an important component in the inventory), on-road engines, non-road vehicles, and non-vehicular diesel engines. This is a major shortcoming in the assessment of the effects of RDF-2006 on emissions. I also question whether the interdependence of MAHCs, PAHCs, specific gravity, and Cetane Number allow determination of the emissions effect of changes in individual properties.

APPENDIX E: Baseline and future year inventories from the EMFAC emissions model contain the uncertainties inherent in the model. Particularly troublesome are predictions for years in which the numbers of diesel vehicles with aftertreatment devices become significant. There is no way to project durability of emission systems, deterioration in emissions control, or the effect of fuel composition on emissions from in-use engines. It is highly likely that the EMFAC projections are optimistic.

APPENDIX F: The results of an EPA regression analysis of the relation between emissions and fuel properties are presented. The signs of the coefficients (slopes) are consistent with understanding of physical processes. The presentation is limited to effects on NO_x emissions. Effects on PM emissions should also be presented.

APPENDIX G: Provides pump wear data related to lubricity.

APPENDIX H: Provides a comprehensive review of technology available for reducing sulfur levels in diesel fuel.

APPENDIX I: Describes diesel engine lubricating oils and discusses current understanding of the relation between lubricant composition and emissions.

APPENDIX J: Provides background information on effects of the proposed regulations on greenhouse gas emissions, including a full fuel cycle analysis.

APPENDIX K: Discusses potential effects on water quality, judged to be negligible.

APPENDIX L: Records the questionnaires provided California refiners.

APPENDIX M: Contains spreadsheets that record the details of the economic impact on California agriculture.

APPENDIX N: Assesses the impact of fuel taxes on purchases of out-of-state diesel fuel and explains the excise tax balancing between states based on where the fuel is consumed.

APPENDIX O: References